

# **Estimating service related traffic demand from trip chain data**

Sebastian Schneider\*, Axel Wolfermann  
\* Corresponding author

German Aerospace Center (DLR), Institute of Transport Research  
Rutherfordstr. 2, 12489 Berlin, Germany  
phone: +49-30-67055-286, fax: +49-30-67055-283  
sebastian.schneider@dlr.de  
axel.wolfermann@dlr.de

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### ABSTRACT

Commercial traffic constitutes a significant part of traffic. While on long distances goods traffic prevails, in metropolitan areas service related traffic (i.e. traffic resulting from services delivered to customers at home, offices, constructions sites etc.) takes the lead – and is growing. This kind of traffic is primarily passenger traffic, but for commercial reasons. Even though goods (e.g. tools) might be transported together with the person (agent, worker etc.), the major purpose of service trips is the movement of the person.

It is common practice to forecast transport demand for private passenger traffic and goods traffic. Dedicated models for service traffic are still rare. This is not only due to the lacking recognition of the particularities of this special part of traffic among transport planners, it is also due to the complexity of analyzing and depicting service traffic.

One characteristic of service traffic is that it consists of tours connecting sometimes more than one destination with the origin of the tour. Many trips are trips with commercial vehicles, registered by a company or organization, but also private vehicle owners use their cars for commercial trips. Because surveys can only collect information on trip chains for a sample population, a method is needed to derive the total demand from this sample. Surveys on private and commercial vehicles used for service trips are particularly useful for this purpose.

This article introduces such a methodology to extrapolate traffic demand from trip chain data. It is not only applicable to service traffic, but to all tour based traffic.

## INTRODUCTION

This article describes a method to generate traffic demand from trip chain (tour) data. It is used to model the traffic demand created by service traffic. Firstly, the reasons are provided why such a model is very useful in the context of transport planning. The role of commercial non-freight traffic, and service traffic as a subset of it, has to be understood to follow the reasoning behind the application to service traffic. This role is addressed in a background section.

This section is followed by an overview of service traffic modeling, describing existing general modeling approaches and their applicability to service traffic. Tour based modeling based on trip chain data is identified as a promising branch of modeling and therefore expanded upon. Subsequently a model to derive initial service traffic demand from trip chain data is presented. This model has been applied to Berlin, Germany as a case study and proved to deliver valid results. The outlook outlines the potential of the model beyond the used data sources and the case study, and introduces possible paths to further enhancement of its capabilities. The article is based on a doctoral dissertation (1).

## BACKGROUND AND MOTIVATION

### Commercial non-freight traffic

Traffic is commonly distinguished according to the vehicle “load” into transport of people (non-freight traffic) and transport of goods (freight traffic). Another distinction refers to the reason for the trip and leads to private and commercial traffic. In the past, commercial traffic was nearly exclusively regarded as freight traffic with the focus on long distance trips. But many trips, particularly in metropolitan areas, are neither conducted by persons for the satisfaction of their private needs, nor conducted for the transport of goods. These trips are addressed by the term *commercial non-freight traffic*. Commercial non-freight traffic comprises *service related traffic* (or just *service traffic*; this traffic will be elucidated further down) and business travel. The different categories of commercial traffic with their major properties are:

- freight traffic  
(load: goods, transport means: goods vehicles; road, rail, vessels)
- service related traffic  
(“load”: mainly people, e.g. tradesperson, contractors; transport means: passenger cars, vans, LDV)
- business travel  
(“load”: people; transport means: passenger cars, trains, airplanes)

The determination of passenger traffic demand is commonly based on household surveys and excludes commercial trips to large extent (Broeg and Winter (2) state up to 50 % of commercial trips not being considered in household surveys). The same applies to the determination of freight traffic demand, which is based on the transported commodities and, thus, also does not incorporate commercial non-freight traffic.

Commercial non-freight traffic, i.e. the transport of people for business reasons, represents, however, roughly twenty per cent of the total urban traffic (3,4) – and a general trend of commercial non-freight traffic increasing can be observed (5). While the share in statewide traffic is yet smaller, it is predicted that in Europe it is particularly the regional commercial non-freight traffic that will grow (6). It is important to note that the drivers and influencing factors for the transport of goods and passengers can differ significantly. A dedicated analysis of both types of trips is thus commendable.

Cambridge Systematics Inc. et al. (7) state that “due to the shift in the United States from a manufacturing-oriented economy to a service-oriented economy, the number of service related commercial vehicle trips is growing faster than the number of trips for other purposes.” The same study evaluated various U.S. statistics to estimate the share in vehicle miles travelled (VMT) by commercial non-freight trips. The numbers are divided by vehicle types. Up to 13 % of total VMT in urban areas in the U.S. are travelled by

service vehicles, which does not include private vehicles used for commercial trips. Furthermore, the share varies according to time of day, underlining the importance of dedicated studies of commercial non-freight traffic. Hunt, Stefan and Brownlee (8) state that about 12 % of VMT in the urban areas of Calgary and Edmonton, Canada, result from commercial trips. 30 % of the stops during these trips were for service deliveries, as compared to 25 % for transportation and handling services.

In the case of Germany, Steinmeyer and Wagner (9) state that 10 % of the annual road performance of private passenger cars is in fact commercial traffic, while for passenger cars registered by companies the share is as high as 45 %. Newer data states that even a share of 70 % of total kilometers by commercially registered passenger cars are travelled for commercial reasons (10). Furthermore, the number of light duty vehicles with less than 3.5 t payload, vehicles used particularly for commercial non-freight traffic is increasing, as opposed to the number of heavy duty vehicles.

This review suggests two important conclusions: data on commercial non-freight traffic is not easy to compare due to the lack of a consistent definition of commercial non-freight traffic and data sources relating to such a definition, but it is nevertheless clear that a significant part of total traffic consists of commercial non-freight trips.

### **Service traffic as a subset of commercial non-freight traffic**

Different definitions have been given for commercial non-freight traffic (a discussion can be found in (11)). It is apparent, that neither vehicle types nor vehicle owners nor trip purposes are sufficient to distinctly divide commercial non-freight traffic into clearer categories or separate it from freight traffic. In many cases private trips are combined with business trips and freight is transported together with people. Regardless, a definition is necessary for drawing a line around the research related to commercial non-freight traffic. It is, however, important to be aware that this line will always be fuzzy.

In the current paper the focus is on service traffic. Service traffic is mostly realized on the road, the trip purpose is a service delivered to a customer and freight is only transported to enable the realization of this service with the transport of the person doing the service being the main reason for the trip. In urban areas this part of commercial non-freight traffic is the most important (about 20 % of urban traffic volume is service traffic according to (12)). Examples for service traffic are tradespersons visiting a customer, a contractor visiting a home to fix a broken facility, workmen driving from their firm to a construction site and the like. Most of these trips are conducted with passenger cars, vans or light duty vehicles (<3,5t GVWR). Also public services (street cleaning, ambulance, police etc.) and traffic of public transport (taxis, buses etc.) can be regarded as a part of service traffic.

The reasons for focusing on service traffic are its importance (share of total traffic) and its particularities and therefore the need to regard it separately from other types of traffic to understand and influence it. This focus is challenging due to the scarcity of data. Public planning yet pays little attention to the particular needs of service traffic (13) and, thus, maintains rarely useful data or models to estimate or visualize service traffic (14). A changing awareness of the importance of service traffic, however, is noticeable. In many cases data might be existing, but not easily available due to its proprietary nature, or the representativeness of the data is questionable owing to the variation of firm sizes, commodities and services (15).

Different data sources have been combined to understand the drivers behind service traffic, thus elucidating the internal workings of companies and the passenger traffic caused by them (11). Aguilera (16) collected evidence on the need for business travel and the profiles of mobile workers by evaluating available literature. Some knowledge on drivers behind service traffic are thus already available. Both studies however did not specifically provide a method to quantify and predict service traffic.

## **Quantification of service traffic**

Cambridge Systematics (7) approached commercial traffic, including service traffic, from statistics related to certain vehicle types. This study provides estimates on the magnitude of service traffic. Also Gliebe, Cohen and Hunt (15) created an intra-urban commercial vehicle model to be run in a disaggregate microsimulation environment based on establishment survey data collected by the Ohio Department of Transportation. A similar establishment survey with the impressive sample size of more than 7000 establishments was conducted in Edmonton and Calgary, Canada, for a similar purpose (8).

In Germany, the increasing awareness of the relevance of commercial non-freight traffic and the realization of the knowledge gap with regards to trips done with light duty vehicles and passenger cars for commercial purposes led to the inauguration of a dedicated survey. “Motor vehicle traffic in Germany” (KiD, (10)) is a survey commissioned by the German Federal Ministry of Transport, Building, and Urban Development (BMVBS). It was conducted in 2010 for the second time (the first one dating from 2002) and focuses on vehicles with less than 3.5 t payload. It is based on drivers’ logbooks of one day. It covers the trips of more than 70,000 vehicles with trip purpose, times, and locations. The population for the survey is the sum of all German vehicle owners. By accessing the data available at the Federal Motor Transport Authority (KBA), a stratified sample could be drawn from the population taking vehicle related information (e.g. vehicle type) and vehicle owner related information (e.g. economic activity class, firm size as number of employees, spatial category of firm’s location) into account. Thus this survey complements household surveys focused on trips for private purposes. The survey provides valid data on national level on commercial non-freight trips.

Though this survey provides little insight into the reasons for commercial trips, it creates a link between demographic and spatial features and commercial traffic. By combining regional data about businesses, employees, and registered vehicles with the national behavioral data about trip generation and vehicle kilometers travelled (VKT), it is possible to generally quantify commercial non-freight traffic, as has been done by Steinmeyer and Wagner (9).

In order to quantify service traffic in more detail for any given area (e.g. a city), more sophisticated methods are needed. Knowledge on trip chains as well as spatial and demographic data is now available and can be used for such methods. If the initial traffic demand can be computed, traffic models can be used and the traffic can be assigned to the road network. Models are powerful tools to support decision making and transport planning. These models for the assignment of traffic to the road network are readily available.

Deriving initial demand out of the available data on service traffic is addressed in this paper. While the model to compute initial demand described in this paper uses data from the KiD survey mentioned above, it is generally applicable to other trip chain data as well. While the trip chain data gives the required information of which origins are connected to which destinations (by what kind of vehicle and at which time etc.), demographic and spatial data links this general information with the specific research area.

## **SERVICE TRAFFIC MODELLING**

### **Commercial non-freight traffic modeling**

Numerous traffic demand models have been developed in the past, starting with personal traffic already many decades ago. Later on existing modeling approaches have been adapted to freight traffic. While in freight traffic, macroscopic models based on the four step algorithm are still the prevailing modeling principle, particularly passenger traffic models moved on to microscopic agent-based approaches. Thus modeling approaches exist for both passenger traffic and commercial traffic. But as has been pointed out before, both scopes leave a gap for commercial non-freight traffic. Fortunately, the existing models provide valuable experiences and tools that can be transferred to commercial non-freight traffic.

In commercial non-freight traffic, per definition, the passenger is the determining element of the traffic, even though goods might be transported as well. Freight traffic models are consequently of little use to model commercial non-freight traffic. Then again passenger traffic models focus on trips done for private purposes and neglect service trips. In commercial transport, different aspects influence decisions than in personal transport (such as different business models, pricing strategies, or advertising campaigns). With business administration, a distinguished field of science has been developed to optimize actions of companies, which sometimes affect many trips at the same time.

For commercial traffic forecasting, (7) list promising approaches, namely aggregate demand models, network based quick-response methods, model estimation methods based on the four step algorithm, tour based models, supply chain models, and combined tour based/supply chain models. The former methods only provide very rough information on commercial traffic (e.g. total VKT). Macroscopic approaches derived from the four step algorithm emphasize trips rather than tours and thereby miss the essential tour based nature of urban commercial vehicle movements (17).

This leaves tour based methods as a promising way of modeling commercial non-freight transport (18).

### **Models based on trip chains (tours)**

In passenger transport modeling, one approach is multi-agent transport simulation, which is designed to replicate day plans of individual agents. The trips made by individuals are hereby derived from the individuals' activity plans, e.g. for a single day, week, or month. These activity plans can be replaced by trip chain diaries of vehicles used for commercial non-freight transport (or more specifically, vehicles used for service related trips), and the models adjusted to account for the particularities of commercial traffic (i.e. different actors and factors influencing demand).

Activity-based multi-agent simulations require initial demand patterns to start with. During a number of iterations, this initial demand is then altered to take into account other effects such as congestion, experience, social lag. A lot of research has already been spent on developing such models. At the same time, the generation of initial demand is still a challenge (19).

A very early model incorporating service traffic is the commercial vehicle travel model by the Atlanta Regional Commission (20). Due to its focus on vehicle emissions, it does not dive into the details of commercial non-freight traffic, but uses very simple trip diaries for commercial vehicles.

A much more advanced model addressing the challenge of commercial non-freight traffic is a traffic demand model developed for Calgary, Canada (17). The model is (like the Alberta model) an extension of a freight model, focuses on commercial vehicles, and includes service trips. The model makes heavy use of logit models which are calibrated for observed data. Changes of tour patterns over time, hence, require panel data to be incorporated into the model. The model is based on traffic zones, for which demographic and business data is aggregated.

### **Trip chain data of commercial traffic**

A prerequisite for applying tour based models is the availability of trip chain data. This trip chain data has to consist of complete trip diaries providing information on individual trips. In case of service traffic, vehicle owners are a valuable source for trip diaries, because tours are nearly without exception conducted with road vehicles and vehicle owners can comprise both companies and private (or self-employed) persons. This also avoids vehicle tours being reported several times due to more than one person using the same vehicle. Attributes of trip diaries are often trip length, duration, purpose, times, number of drivers/passengers, type of vehicle, and so on. Trip chain data can be seen as the most "raw" data in the field of transport, as it directly

reflects actions in reality and does not depend on assumptions or considerations (“What would you do if the price for gas increased by 2\$?”).

One source for trip chain data are empirical surveys that are collected by authorities. The survey conducted by the “Denver Regional Council of Governments” (DRCOG) in 1998/1999 (see also (18)) is one of the rare examples, another being the survey “Motor vehicle traffic in Germany” (KiD, (10)) mentioned above and conducted in 2002 and 2010 so far. Another source for trip chain data are automatic IT systems that are maintained by operators for reasons such as knowing where trucks are (fleet management), invoicing, meeting legal requirements such as the number of breaks employees are required to have, and so on. Especially for invoicing, often the distance and times a truck has been driving to a customer’s site is on record. These data records can be retrieved in order to maintain a large number of trip chain records at relatively low cost, since the data is already being collected for other purposes. However, the information content of this data source is often limited to fewer parameters and specific companies and access to the data is subject to privacy concerns. Thus it is harder to achieve representative samples.

### **Trip generation rates**

Trip chain data has to be combined with data on trip generation rates to derive total demand. Trip generation rates are often specified with reference to distinct parameters such as business sector, company size, or vehicle type. If both trip chains and trip generation rates (number of trips) can be linked based on similar attribution, the total traffic demand of a region can be derived in a disaggregated way leading to more precise (less aggregated) and more accurate results.

Trip generation rates can be collected through empirical surveys in which companies, private households or individual persons, that is the entity that causes traffic, tells how often trips are made. If further information is available such as the trip purpose, the two data types can be accurately linked to each other. The result is information on how many trips are generated by the respective entity (generation rates), and further the nature of trips (trip chain data).

### **Spatial data and population data**

For using the previous two data types in a model which has to map the demand to a specific area, spatial data as a third data type is vital. Spatial data is available at high resolution in national databases for most industrialized countries and can be obtained particularly for the US at no cost. Out of the vast potpourri of spatial data that can be found, land-use is of most significance to transport. By extracting features in the trip chain data, these can be linked with other spatial data sets such as land use and (synthetic) populations of firms and private households. For example a model can thus ensure that a generated home trip actually points to a private household located in a living area opposed to other buildings located in an industrial area.

A big advantage is the fact that designated land-use models can be used to forecast changes in land-use, therefore allowing traffic predictions based on forecasted land-use data. Or forecasted population data may be used to predict effects such as changes in age distribution or economic business structure.

## **MODEL DESCRIPTION:**

### **EXTRAPOLATION OF TOTAL DEMAND FROM SAMPLE TRIP CHAINS**

With a representative sample of trip chain diaries at hand, a methodology is developed that “clones” these trip chains in order to generate the total transport demand of a given study area. In order to meet the requirements from the background chapter, the model is designed as an urban, fine-granulated multi-agent transport model in which each vehicle is modeled separately. Vehicles (or agents) are modeled by “cloning” the behavior that is found in the observed trip chain diaries. This is done for every entity for which the traffic generation rates suggest to do so. Detailed information on the methodology can be found in (1).

As a prerequisite, spatial and demographic data is used to create the simulation substrate, i.e. an electronic map in which all spatial and demographic features are placed in a computer readable format. The model then “fits” the observed trip chains into the modeling world. Here, the process reproduces the characteristics of the trip chain with regard to the characteristics of the target area (e.g. trips to a warehouse must point to the location of such). The model takes into account that the sample trip chains were not collected in the same area.

The methodology consists out of three consecutive model steps:

- Creation of simulation substrate
- First a modeling world is created that combines the spatial and economic data for the study area. The result is a digital map in which all buildings, private households, land-use areas, company sites and so on are on record. Where available, entities are specified by attributes such as firm size, economic sector, number of vehicles, and others. With the spatial data at hand, this goes down to the level of separate buildings, therefore each location is defined by street, house number, and zip code.
- Determination of traffic generation rates
- For every company inside the study area, the number of trip chains originating from the company is derived from empirical trip generation data that specifies how vehicles per average work day operate on behalf of companies of specific types.
- Trip chain assignment
- For each company, this number of trip chains is then generated by the algorithm. This is done by “cloning” trip chain diaries which are taken from one of the data sources mentioned before. For this purpose, the concept of “template logbooks” is introduced. By processing every company within the study area, the total demand can be obtained.

The model system  $M$  can be expressed as

$$M = (C, B, H, R, I)$$

with

- |     |   |
|-----|---|
| $C$ | set of all locations that are distinguished by the model and that can serve as source or destination of trips, best specified by street, house number, and zip code   |
| $B$ | set of all businesses in the model world. All or a subset of these can generate trips as defined by the traffic volume data   |
| $H$ | set of private households. These can be the source or destination of trips that are coded as starting or ending at a household  |
| $R$ | repository of template logbooks, that is a set of observed trip diaries. Each template logbook specifies the type of vehicle, its company or household characteristics and the spatial route pattern as shown in FIGURE 1.  |
| $I$ | set of instructions that tell how to assign logbooks from the repository $R$ to the simulation substrate. The assignment can be specified by a number of constraints that can be freely chosen according the model area and transport type to be modeled. The constraints define the linkage of trip chains and spatial data. |

The principle algorithm that is carried out for every entity in the study area with a traffic generation rate greater than zero works as follows:

Starting from the entity’s location  $x_0$ , the trips are generated one by one in a recursive manner. The algorithm starts by first selecting potential destinations that comply with the constraint set for trip number one  $C_1$ . The constraint set may consider a large number of aspects depending on the data at hand.

$$C_1 = \text{restriction}_1 \dots \text{restriction}_n$$



In a simple case, this can be for instance the distance between the entity's location and the potential destination  $z_i$  as well as the destination type (e.g. a trip of five miles distance that leads to a private household would result in the set of all private households that are located at a five miles distance from the location of that entity):

$$C_1 = \text{distance}(d \leq 5) \text{ AND destination}(\text{type} = \text{private household})$$

In case of the logbook's first trip, from all locations within the synthetic world that comply with these constraints one location is randomly chosen and used as start for trip number two (the other locations are kept for fallback in case that the selection will prevent subsequent trips to be applicable later on). For trip number two onward, the location with best spatial fit is selected, where spatial fit refers to resembling the geometric distances between the logbook's waypoints and its starting point ( $z_i$  in FIGURE 1) for taking into account the template logbook's spatial extent (compare Tour 1 in FIGURE 1 with limited spatial extent to Tour 2 with high spatial extent).

All trips are generated in the same way, except that the actual constraints vary from trip to trip according to their specific attribution (such as changing trip purposes, destination types, and distances). The process is repeated for all trips. In case that the algorithm fails to clone a trip due to that the constraint set does not allow the placement of the trip into the study area (for reasons that the trip's characteristics does not comply to the spatial features of the study area), the algorithm steps back and tries one of the other possible destinations from the previous trip until a valid solution is found. The algorithm also terminates if no possible solution can be found (this happened in the case study only in very few cases, for which the constraints may be eased), see also (1).

The algorithm requires the first trip of a trip chain to start where the entity is located, that is a trip chain of the kind "home – office – customer – office – home" works well if the entity in focus is the individual person that starts from "home". If, especially with regard to modeling commercial traffic, the firm / office is chosen as traffic generating entity (for which traffic generation rates were obtained), the trip chain is pre-processed beforehand. Here, the trip chain is split at waypoints of type "office", resulting in three distinct "sub-trip chains" (home – office; office – customer – office; office – home). The resulting sub trip chains can then be processed in the normal way. By this, the procedure does not eliminate or alter the trips itself, ensuring that the original information is kept and the original trip chain is properly cloned.

Which template logbooks are selected for a given company can be specified in many ways. One is to require certain attributes of the template logbooks and of the simulated company to be identical (e.g. equal company size, business sector or rural vs. urban based). From those that meet the requirements, logbooks might then be chosen by random or weights can be applied. An alternative is to incorporate some empirical finding that tells what behavior is typical for firms with given characteristics. With the model being implemented as software code, generally any kind of assignment procedure from complex to simplistic is thinkable.

The trip chain data is "cloned". It is not altered as is the case in most behavioral models. This approach was chosen due to the lack of behavioral data on service traffic. Expected changes over time can be considered in the described approach by altering the input data based on assumptions or separate models (e.g. altering spatial data, trip chain data, trip generation data). In this way the approach can incrementally incorporate insights into behavior of service traffic actors.

## MODEL APPLICATION

To prove the viability and validity of the methodology, it has been applied to a case study area. This section introduces the case study and the obtained results. It is shown that the methodology is applicable, and

reasonable values can be obtained. The results are validated via comparison to reference data by Steinmeyer and Wagner (9) for traffic volumes by vehicle type and vehicle kilometers traveled.

### Scope of case study

The case study simulates service transport trips within the entire city of Berlin, Germany. The city covers 892 square kilometers and is home to roughly 3.5 million inhabitants. Simulated trip chains can contain both commercial and private trips. If a service technician for example goes home for lunch and thus generates private trips within a chain of commercial trips, these private trips are modeled as well. The time frame is one average work day. Traffic on behalf of all companies inside the study area is generated.

### Input data

Trip chains were taken from the empirical survey KiD (21). Land use data was taken from the BKG (Bundesamt für Kartographie und Geodäsie), a national authority for the provision of spatial data for Germany. The data defines water bodies, forest, industrial areas, living areas, areas of special use such as hospitals, commercial areas and others. While the dataset provides a large number of different land use types, the following four were selected for the simulation due to their significance on non-freight commercial transport:

- Residential area: mainly buildings for housing and living purposes, including places for shopping, culture, religion, handcraft, and health services.
- Industrial area: mainly used for industrial and commercial purposes, e.g. storage depots, large-scale commercial operations, and shopping malls.
- Mixed-use area: an area where no specific use type dominates, mostly occurring in rural areas and inner city districts that combine retail, housing, and public services.
- Special-use area: public administration, health, education, science, culture, recreation, and military use.

Another layer of house records was obtained as well, showing the location of all postal addresses where a solid structure has been built. Buildings serve as possible destinations of trips. By taking together the previous two data sets, trips will point to exact buildings located within the four land use types.

Finally, trip generation rates were taken from a dedicated survey on commercial non-freight transport (6). In particular the survey tells the number of times a customer site is visited by a company representative via road transport on an average work day. All data sets have in common that they distinguish firms by their economic sector (branch) as well as their size (measured in number of employees). The data sets from above were then combined into a synthetic economic structure to form the synthetic study area.

### Selection procedure

The mapping between template logbooks and firms is chosen to resemble equal attribution for economic sector and business size. In the likely case that more than one logbook with identical attributes exists, one is selected by random with no weight applied (uniformly distributed).

### Constraints

The set of constraints that limits the degree of freedom that is given to the algorithm for applying the template logbooks from the logbook repository (i.e. the universe of all logbooks) to the synthetic world (that is population data and spatial data for the study area of Berlin) was defined as follows:

A first constraint required the *trip sequence* of the generated trip chain to be the same of the original trip chain (from the template logbook). If for example, a template logbook states the first trip to point to a

private household, a trip to a household is then generated. If the second trip pointed to a business site of the economic sector 'I', a trip pointing to a business of that kind is generated. While it was decided to maintain the original trip sequence for the current demonstration example, the algorithm may be altered to allow for changing the order of trips. What constraints are implemented is subject to the overlap between the template logbook attribution and the (spatial) synthetic world data. The attributes from the empirical survey KiD were linked to the synthetic world data as follows:

- **Terminal / station / port / airport:**
  - destination must be within land-use “special“
- **Forwarder:**
  - destination must be a firm of the transport sector
- **Construction site:**
  - any location/no restriction applied
- **Own company:**
  - forced stop at the own company site
- **Other firm:**
  - destination must be a firm that is not the own
- **Private household:**
  - destination must be a private household
- **Other business-related destination:**
  - any location
- **Private destination:**
  - any location
- **Branch office:**
  - destination must be a firm sharing the own economic sector

A second constraint required maintaining the *trip length* for each generated trip. Hence, template trips of  $x$  kilometers will also show  $x$  kilometers in the generated demand set. For simplicity reasons distance was defined as the direct airline distance. Alternatives are driven / routed distance or time. In order to allow for small differences, trips were set to differ up to 50 m from the original template logbook.

And thirdly, *round trips* by their nature were required to start and end at the same location.

## Results

During simulation, a total of 133,538 vehicles were processed. Of these, 130,407 (or 98 %) could be successfully applied to the spatial data. The algorithm therefore was flexible enough to clone most trip chains despite the (different) spatial characteristics provided by the area. At the same time, the algorithm ensured that neither the trip distances nor the waypoint types of the template logbook were altered. That is, the activity sequences of the template trip chains are kept unchanged.

Note that for each simulated vehicle a logbook was cloned. For most business size / economic sector combinations, the algorithm could choose from more than 100 template logbooks. Only for seven combination pairs the number of template logbooks was below 100, and for three combination pairs below 50. In total, the repository contained 11.757 template logbooks. It should be added however, that universal constraints such as 8 hours working shifts suggest that certain groups of people generally follow similar travel patterns; therefore much fewer template logbooks are actually required for applying the methodology. However, with higher case numbers, the advantage is that extreme cases are also represented in the simulation results.

The model results have been validated by comparing it to results from (9), who published estimates for service traffic for the city of Berlin. This validation approach was chosen due to the lack of data on

service traffic. Traffic counts cannot reliably distinguish between private and commercial traffic, and surveys explicitly addressing commercial non-freight traffic are scarce.

In relative numbers, they observed 62 % of total traffic to be passenger cars and 34 % accounted for trucks with up to 3.5 tons of payload. In the current simulation example, a share of 37 % of trips were by trucks, and 60 % are made by passenger cars (see also FIGURE 2). In absolute numbers, Steinmeyer and Wagner estimated a total of 510,000 daily trips in comparison to 521,000 in the simulation. Further similarities can be observed for the kilometers driven: traffic demand from the model assigned to the road network leads to 13.5 million VKT and, thus, results, as expected, in a slightly greater number than Steinmeyer and Wagner (11 mio. VKT for commercially registered vehicles only). The share for passenger cars is consistent (70 % vs. 71 %).

Furthermore, FIGURE 3 shows the distribution of trips in space, i.e. a map of Berlin with the number of incoming and leaving trips of the different districts provided by the model. The concentration of traffic in the city center and the densely populated districts can be seen. Cells with high trip volume on the outskirts of the study area are caused by the fact that the algorithm cannot distribute some trips properly at the boundary of the study area. This could be ameliorated by extending the model area beyond the study area. This map could also be differentiated for different vehicle types, time of day, or trip purpose.

FIGURE 4 on the next page shows the distribution of trips in time, i.e. a departure time histogram for all trips. Typical morning and evening peaks can be found in the diagram for all simulated trips (g). FIGURE 4 (a) to (f) details the departure times for different trip purposes. This kind of diagram can easily be computed for different areas or even single cross-sections (e.g. on major roads).

While the data behind these diagrams are not model constraints and the characteristics were just passed through the model, they make the simple selection procedure “equal attribution” seem plausible, because disproportionately high selections of non-typical “extreme” logbooks and programming bugs would have led to visible undesired effects. For example, if a logbook with many night trips had been over-sampled, FIGURE 4 would no longer show the representative line.

The average number of trips per vehicle in the simulation is 3.69 trips, hence being within the corridor of 3.6 to 3.8 trips per day during weekdays that was observed in (22). Again, if many logbooks with many trips were picked disproportionately too often, that rate had turned out different.

The simulation took 42 hours on an Intel Xeon 3.00 Ghz with 12 GB RAM. This is the equivalent to 0.29 seconds per trip and 1.13 seconds per firm and template logbook. The current implementation was not optimized for processing speed yet and can be improved by changes in both hardware and software.

## CONCLUSIONS AND OUTLOOK

It has been shown that service traffic as a subset of commercial traffic is an important part of traffic, particularly, but not only, in urban areas. It has been described how service traffic differs from freight traffic in the trip purpose (service delivery), vehicle load (mainly people, not goods) and the vehicle type (mainly passenger cars, vans, light duty vehicles). Service traffic requires special attention in order to consider it appropriately in traffic forecasting and transport planning. Furthermore, service traffic will gain increasing relevance in the future due to the changes in demography and economic structures. To get a clear picture of service traffic, dedicated models are a very helpful tool.

This paper introduces a methodology to quantify service traffic for any given area (the city of Berlin, Germany, has been shown as a case study), based on spatial data, trip generation rates, and trip chain data. The methodology is able to derive the initial traffic demand from trip chain samples. This traffic demand can be fed into traffic assignment models to visualize the resulting traffic and to incorporate a feedback of traffic conditions affecting traffic generation. This makes the model very flexible in terms of transferability and combination with other models (e.g. for goods traffic and personal passenger traffic).

Business sectors, land use, number of employees and similar parameters are used to link trip chains to single firms. A set of constraints is defined to map sample trip chains (logbook templates) to the modeled area. These constraints can be sequence of destinations, distance between destinations and base of the trip, but other constraints can also be defined.

The case study showed that the model delivers plausible results. It could even be demonstrated that the model can be applied to a much larger area, namely the whole of Germany, without major adjustments. A validation of the results on this level, however, is only possible to limited extent due to the lack of validation data (which underlines the need for such a model in the first place).

Future research includes using routing distances instead of the currently used airline distances (to the price of increased computing time). Also any traffic flow simulation can be used to provide the required data and to assign the generated traffic demand to the road network. Due to the high level of spatial resolution (low granularity), the model can easily be connected to microscopic or agent-based simulations.

In order to use the methodology for forecasting or scenario testing, the model can be linked to land use models and also models predicting changes in trip chains and trip generation rates of specific vehicle types and business sectors. Moreover, the described methodology is not limited to service traffic or motorized vehicles, appropriate data provided. The increased availability of trip chain data not only collected by surveys, but also by modern IT systems, makes the methodology even more attractive.

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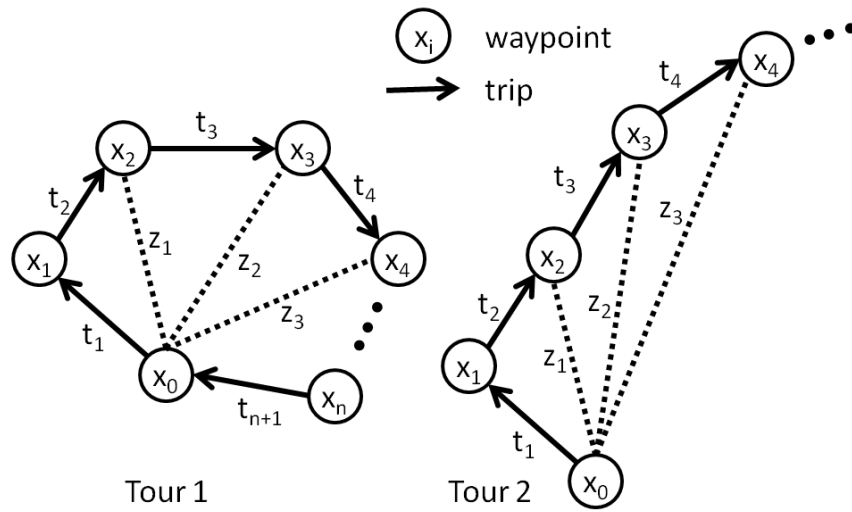
**FIGURE 1 Two Template Logbook Examples Consisting of  $n$  Trips.**

**FIGURE 2 Comparison of Simulation Results and Results From (9)**

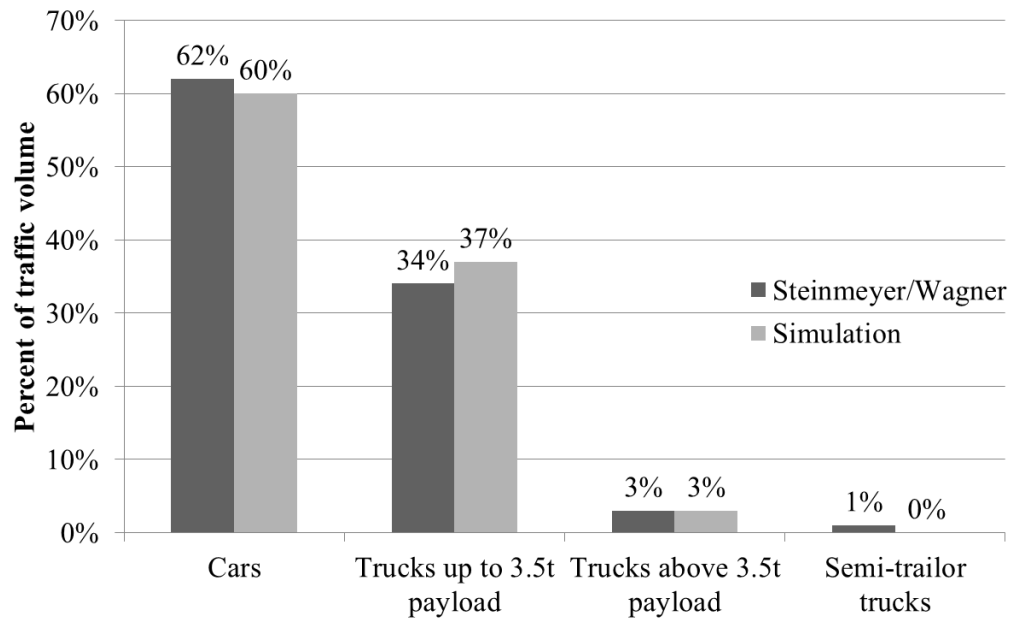
**FIGURE 3 Distribution of Generated Trips by City Districts, Incoming and Leaving.**

**FIGURE 4 Departure Time Histograms.**

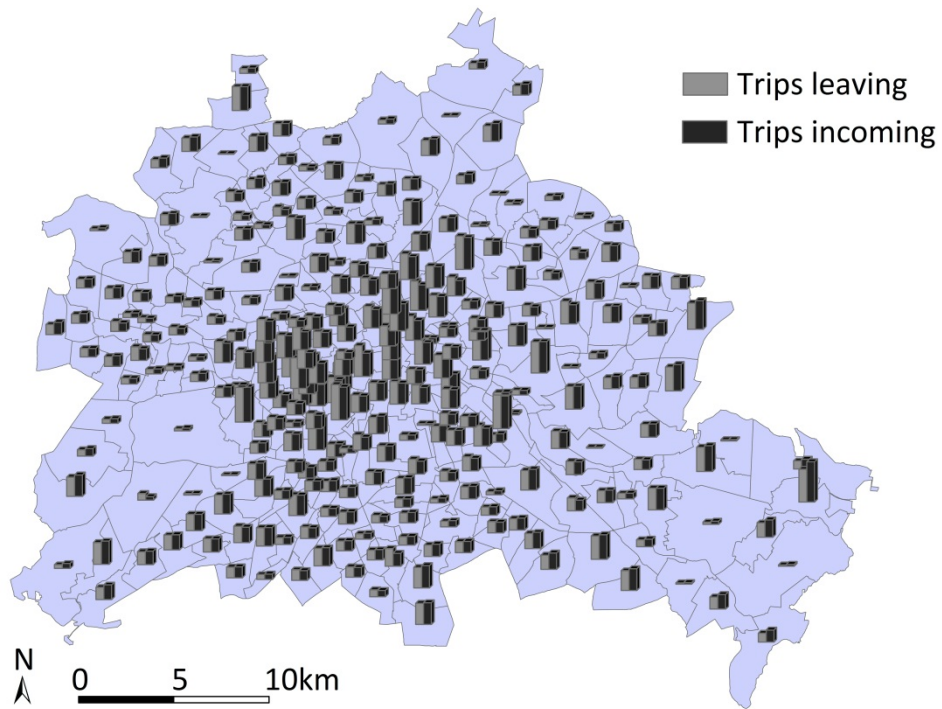




**FIGURE 5 Two Template Logbook Examples Consisting of  $n$  Trips.**



**FIGURE 6 Comparison of Simulation Results and Results From (9)**



**FIGURE 7** Distribution of Generated Trips by City Districts, Incoming and Leaving.

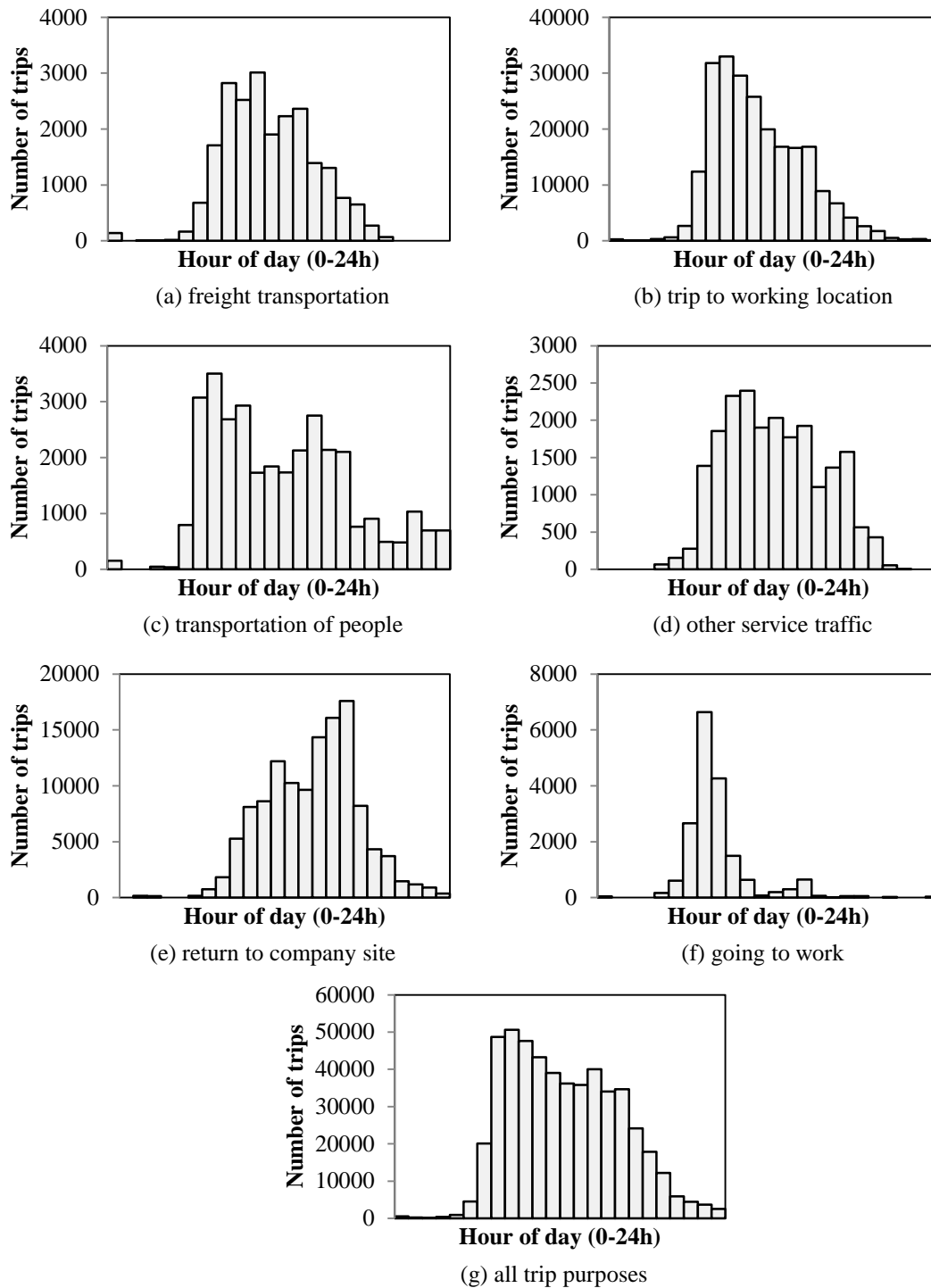


FIGURE 8 Departure Time Histograms.